



Panos Konstantin

# Power and Energy Systems Technologies & Economics

## Case Study Integrated Model Cost Allocation\_Exergy Backpressure CHP

### Notes:

1. Cells with black characters include inputs
2. Cells with red characters include formulas
3. Download of FluidEXL is required

Last update March 2016



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### **Disclaimer**

The Examples are solely and exclusively indented to provide support and assistance to the readers for practicing and better understanding of the theoretical part of this book.

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The author, Panos Konstantin, believes that all information and guidance provided and all calculations in these examples are correct. Nevertheless anyone using these examples should carry out their own due diligence and appraisal of the contents.

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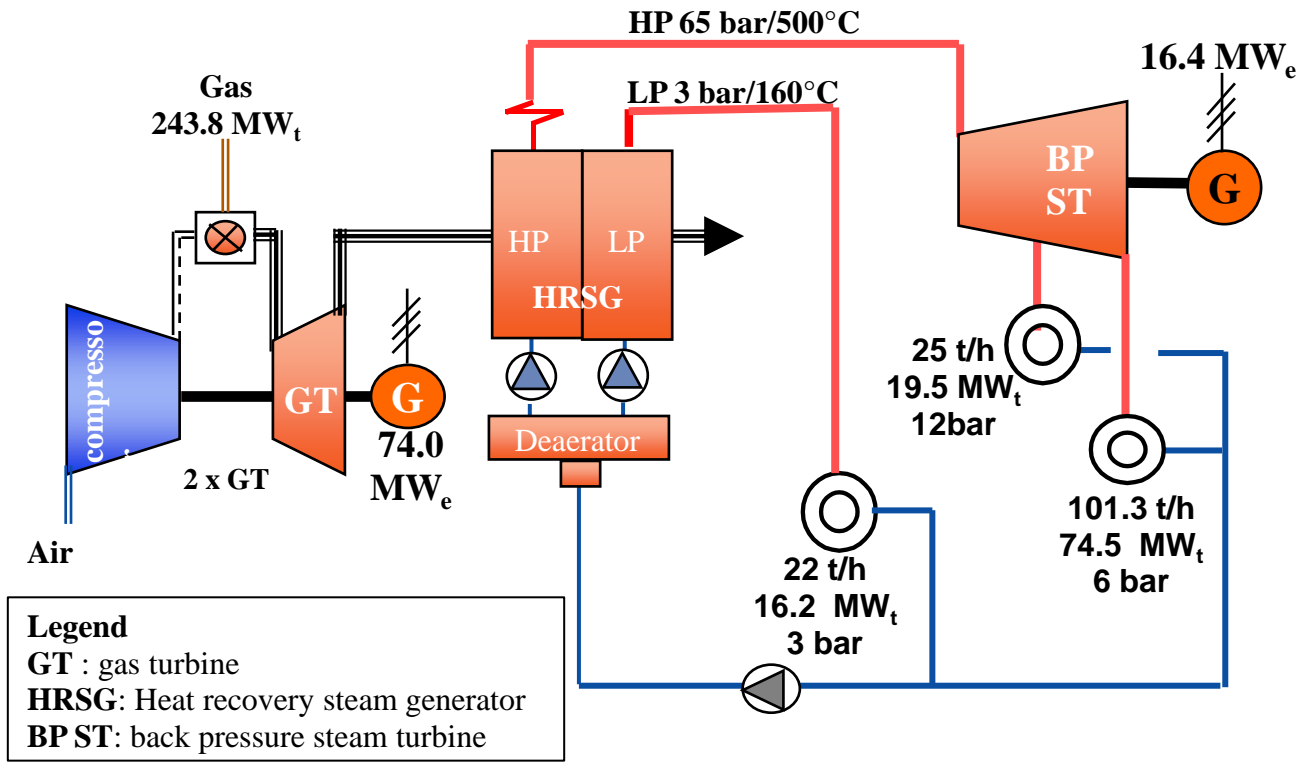
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Proposals for improvements of the contents are welcome and will be considered in upcoming updates!

**Last Update March 2016**



Gas  
243.8 MW<sub>t</sub>

compresso  
Air

2 x GT

74.0  
MW<sub>e</sub>

HP 65 bar/500°C

LP 3 bar/160°C

HP LP  
HRSG

Deaerator

BP  
ST

16.4 MW<sub>e</sub>

G

25 t/h  
19.5 MW<sub>t</sub>  
12bar

101.3 t/h  
74.5 MW<sub>t</sub>  
6 bar

22 t/h  
16.2 MW<sub>t</sub>  
3 bar

| Power and Energy Balance |                                  |             |                 |   |                           |
|--------------------------|----------------------------------|-------------|-----------------|---|---------------------------|
| Item                     | Full load operating hours<br>h/a | Heat        |                 | Electricity                               |                           |
|                          |                                  | Output      |                 | Annual Production<br>MWh <sub>t</sub> / a | Output<br>MW <sub>e</sub> |
|                          |                                  | t / h       | MW <sub>t</sub> |   |                           |
| Steam 12 bar             | 5,000                            | 25.0        | 19.1            | 95,410                                    | 2.6                       |
| Steam 6 bar              | 7,500                            | 101.3       | 73.8            | 553,517                                   | 14.1                      |
| Steam 3 bar              | 7,500                            | 22.6        | 15.9            | 118,898                                   | -                         |
| Gas turbine              | 7,500                            | -           | -               | -   | 74.0                      |
| Total, gross             | -                                | -           | 108.7           | 767,826                                   | 90.7                      |
| Total, net               | -                                | -           | 108.7           | 767,826                                   | 88.0                      |
| own consum               |                                  |             |                 |   |                           |
| Fuel consumption         | -                                | $\eta_{gt}$ | MW <sub>t</sub> | $\eta_{tot}$                              | MWh <sub>t</sub> / a      |
|                          | -                                | 37.2%       | 243.8           | 81.82%                                    | 823,643                   |

| Specific Exergy of the Extracted Heat |                 |             |                   |                    |               |
|---------------------------------------|-----------------|-------------|-------------------|--------------------|---------------|
| Item                                  | Pressure<br>bar | Temp.<br>°C | Enthalpy<br>kJ/kg | Entropy<br>kJ/kg*K | Exer<br>kJ/kg |
| Steam 12 bar                          | 12.0            | 284         | 3,012             | 6.97               | 564           |
| Steam 6 bar                           | 6.0             | 216         | 2,885             | 7.04               | 453           |
| Steam 3 bar                           | 3.0             | 164         | 2,790             | 7.15               | 356           |
| Zero exergy *)                        | 1.0             | 54          | 226               | 0.76               | -             |

\*) Exergy conversion ratio

| Total Exergy of the Extracted Heat |                          |                 |                          |                    |                            |
|------------------------------------|--------------------------|-----------------|--------------------------|--------------------|----------------------------|
| Item                               | Full load hours<br>h / a | Output<br>t / h | Specific exergy<br>MWh/t | Total exergy<br>MW | Annual Production<br>t / a |
| Steam 12 bar                       | 5,000                    | 25.0            | 0.157                    | 3.9                | 125,000                    |
| Steam 6 bar                        | 7,500                    | 101.3           | 0.126                    | 12.8               | 760,097                    |
| Steam 3 bar                        | 7,500                    | 22.6            | 0.099                    | 2.2                | 169,431                    |

| Energy - Exergy Balance |              |              |                   |                              |                   |
|-------------------------|--------------|--------------|-------------------|------------------------------|-------------------|
| Item                    | Output       |              |                   | Energy                       |                   |
|                         | Output<br>MW | Exergy<br>MW | Exergy share<br>% | Annual production<br>MWh / a | Exergy<br>MWh / a |
| Electricity, net        | 88.0         | 88.0         | 82.3%             | 653,673                      | 653,673           |
| Steam 12 bar            | 19.1         | 3.9          | 3.7%              | 95,410                       | 19,598            |
| Steam 6 bar             | 73.8         | 12.8         | 11.9%             | 553,517                      | 95,635            |
| Steam 3 bar             | 15.9         | 2.2          | 2.1%              | 118,898                      | 16,733            |
| <b>Total</b>            | n.a.         | 106.9        | 100.0%            | 1,421,499                    | 785,639           |

| Costs Estimation            |             |               |            |         |                |
|-----------------------------|-------------|---------------|------------|---------|----------------|
| Item                        | Unit        | Fixed Costs   | Item       | Unit    | Variable Costs |
| <b>Financial parameters</b> |             |               |            |         |                |
| CAPEX                       | Mio.€       | 120.00        | Fuel NG    | MWh / a | 823,643        |
| discount rate, real         | -           | 6.5%          | Price      | €/MWh   | 25.00          |
| Lifetime                    | a           | 25            |            |         |                |
| <b>Annual costs</b>         |             |               |            |         |                |
| Annualized CAPEX            | th. €/a     | 9.84          | Fuel Costs | th. €/a | 20,591         |
| O&M Cost                    | th. €/a     | 1.80          | Non-fuel   | th. €/a | 3,369          |
| <b>Total</b>                | <b>T€/a</b> | <b>15,838</b> |            |         | <b>23,961</b>  |

| Costs Allocation   |                   |                        |                  |                      |                          |
|--------------------|-------------------|------------------------|------------------|----------------------|--------------------------|
| Item               | Capacity costs *) |                        | Energy costs **) |                      | Composite cost<br>€/ MWh |
|                    | Fixed costs       | Specific Capacity Cost | Variable Costs   | Specific Energy Cost |                          |
|                    | th. € / a         | € / (kW*a)             | th. € / a        | € / MWh              |                          |
| Electricity, net   | 13,038            | 143.7                  | 19,936           | 29.58                | 48.93                    |
| Steam 12 bar       | 581               | 30.4                   | 598              | 6.26                 | 12.35                    |
| Steam 6 bar        | 1,889             | 25.6                   | 2,917            | 5.27                 | 8.68                     |
| Steam 3 bar        | 331               | 20.8                   | 510              | 4.29                 | 7.07                     |
| <b>Total (***)</b> | <b>15,838</b>     | n.a.                   | <b>23,961</b>    | n.a.                 | n.a.                     |

\*) Allocation based on the Exergy-power share

\*\*) Allocation based on the exergy-energy share

TE-CaseStudy-10\_Cost-Allocation\_Exergy-Balance-Backpressure\_CHP.xls  
Cycle\_simulation

